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Transportation Synthesis Report

LED Warning Lights for DOT Vehicles

Prepared for
Fleet Services Unit
Division of Business Management

Prepared by
CTC & Associates LLC
WisDOT RD&T Program
December 10, 2003

Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research.

Request for Report

LED lights are rugged, long lasting and highly energy efficient. Heavy impact does not bother them, their useful life is about 100 times greater than that of incandescent bulbs, and they use less energy than incandescents to provide the same amount of light[1]. LED traffic signal lights consume 80 to 90 percent less energy than incandescent ones and generally last four to six years longer[2].

There is a growing list of applications for LEDs in automotive vehicles. The brake lights and running lights on many new cars and trucks are LEDs, which provide equally impressive longevity and faster light-up than the incandescent counterparts[3]. A number of state DOTs are beginning to test the use of LED lighting on their maintenance vehicles as replacements for incandescents or in new safety configurations. WisDOT's Fleet Services Unit is examining the potential for equipping the department's maintenance and enforcement vehicles with LED safety lighting on a broad scale, and asked the RD&T Program to help research several related issues:

- Performance. How well does LED safety lighting perform; well enough to consider a comprehensive effort to purchase it instead of incandescent lights?
- Cost. The economy of LED traffic signal lighting is well-documented, but are there cost analyses for LED lighting on maintenance and enforcement vehicles?
- Distribution. Have other agencies or municipalities converted their fleets to LEDs, and what did that process involve?

[1] *LEDs, The Newest Technology for Energy Efficient Lighting*, John Chandler, Maine Department of Environmental Protection: http://www.state.me.us/dep/iob/iob_120.htm.
[2] *Energy-Efficient Traffic Signals*, Consortium for Efficient Energy Inc., 2000-03: http://www.cee1.org/gov/led/led-main.php3.
[3] Ibid.: *LEDs, The Newest Technology for Energy Efficient Lighting*.

Summary

The Fleet Services Unit passed along to us results of preliminary research, which included contact with John Bullough, Lighting Scientist for the Lighting Research Center at the Rensselaer Polytechnic Institute, New York. John and the institute have performed a number of LED studies, including use in traffic signals and on snowplow vehicles. John shared some helpful observations with Fleet and identified several of the studies (see **Research**, below.) John said that in one study, "people could detect when they were getting closer to the back of a snowplow faster with the steady-burning (LED) lamps (mounted on the rear of a snowplow)."

Fleet had also contacted Curt Gegoux, Northwest Region Equipment Superintendent for the Washington State DOT. Curt reported that WSDOT is currently testing LED light utilization in certain vehicle applications: "The jury is still out regarding their longevity and overall cost saving," Curt said, "however, it does look promising." (See **Maintenance Vehicles**.)

Fleet had obtained contact information for two Wisconsin county road managers who use LED lighting on maintenance vehicles. We connected with one of the managers, Lee Sauer of the Marquette County Highway Department, who shared his thoughts on LED usage. (See **Maintenance Vehicles**). "We are now seeing many additional benefits from LED use, including longevity," Lee said.

We augment Fleet's findings with information about the use of LEDs on snowplow vehicles by the Idaho, Minnesota, Vermont and Colorado DOTs. (See **Maintenance Vehicles**.) In an interesting application, two of the agencies are mounting LEDs on the ends of wingplows. The basic information we report below is found in an October 2003 *Better Roads* article entitled *Safer Winter Maintenance*. We followed up by directing e-mail surveys to appropriate staff or departments within the DOTs asking for further details. This information will be forwarded to Fleet as it is received.

To learn about LED use on enforcement vehicles, we contacted the University of Wisconsin-Madison Police Department, which was generous in sharing information about LED startup, configurations and applications, performance, colors and costs. (See **Enforcement Vehicles**.) Security Supervisor James Kaszubski said that, "All of our fully-marked squads have all-LED lightbars, and over half of our non-striped cars have LED lights in them. Scheduling of the change over (to LEDs) is extremely important as you do not want to take your entire fleet down at one time just to install new lighting."

For further information regarding LED costs, we scanned the Web for vendors sites offering LED safety lighting for trucks. The sites are plentiful, but we located just one that listed prices. Below, we identify several vendors who market LED circular and oval-shaped stop/tail/turn lights, lightbars, strobe lamps and cab markers. WANCO Inc. markets a vehicle mounted traffic director that can be fitted with LEDs. (See **Equipment**.) We also directed an e-mail query to Gary Simons, a Wisconsin sales representative for Federal Signal Corporation (FSC), for his take on costs and other considerations involved with equipping DOT maintenance and enforcement vehicles with LEDs. (We were referred to Gary by Don Cash, National Accounts Manager for FSC, who has discussed vehicle emergency lighting and effectiveness with WSDOT.) Gary can be contacted at gsimons@fedsig.com: his reply will be forwarded to Fleet when it is received.

Regarding the performance of LEDs in fleet applications, we located several Web items that speak to the issue. (See **Performance**.) A November 2002 article in *FleetOwner* states that "most fleets are aware of the advantages of LED lamps over incandescent lighting. The average life of an LED lamp -- which is not susceptible to shock and vibration since its electronics are completely sealed -- is 100,000 hours." Merls Bus Sales notes that LEDs "use about 10 percent of the amperage draw of conventional incandescent lighting, resulting in reduced wear and tear on a vehicle's electrical system." In recent comments to the National Highway Traffic Safety Administration, the American Trucking Associations said that, "due to their superior performance, lower frequency of failure (e.g. longer service life), and redundancy (multiple LEDs per device), overall vehicle safety is enhanced [by LED use]."

As John Bullough puts it, "For applications like brake lights and turn signals, it seems a 'no-brainer' in the sense that LED devices tend to be much more efficient and long-lasting than the filtered incandescent lamps they would replace."

Research

Improved Visibility for Snowplowing Operations

NCHRP Research Results Digest No. 250, November 2000.
http://gulliver.trb.org/publications/nchrp/nchrp_rrd_250.pdf, scroll down to "Field Demonstrations."
Extensive laboratory and limited field tests of several snowplow treatments and rear lighting configurations were conducted in this project. Rear lighting configurations included commercial lighting similar to that used by the New York State Department of Transportation, indirect edge delineation using flood lights, two pairs of alternating high-mounted flashing lights (amber and red), and a lightbar using LEDs in a steady configuration. An assessment by snowplow operators suggested that the LED lightbar configuration provided the highest visibility and confidence level for motorists in overtaking the snowplow. Based on this assessment, an amber light configuration employing an array of LED marker lights was developed and used in further field demonstrations.

The research agency for this project was Rensselaer Polytechnic Institute. John Bullough (quoted earlier in this report), added that "people could detect when they were getting closer to the back of a snowplow faster with the steady-burning lamps. In addition, observers rated the steady-burning lightbar as providing better visibility and confidence for judging speed and distance than the flashing lights. The prototype lightbar could easily be adapted to existing maintenance vehicles as a retrofit, or it could be incorporated into specifications for new vehicles.

"The nice thing about an LED array," John said, "is you could have most of them on steady burning with a few flashing to help with 'attention grabbing' which is still important especially on snowplows. LEDs also turn on very quickly compared to incandescents so you can get some 'punch' because of that immediate onset (if the LEDs are wired to do this). Considerations with red and amber LEDs should be to ensure that the colors appear correct to people with color vision deficiency. We did some work on traffic lights that talks about this." (See: Lighting Transformations Program: *Issues and Options Paper*- Section 6- "Visibility," at http://www.lrc.rpi.edu/programs/lightingTransformation/LED/issuesOptions06.asp)

For further information, John may be contacted at- E-mail: bulloj@rpi.edu; Phone: 518-687-7100.

In Curtailing Collisions, Tortoise Beats Hare

Publication date: August 2002.
TRIS Online abstract:
http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00931383&STARTROW=1&CFID=350770&CFTOKEN=12208015.
Anecdotal evidence suggests that transit buses are being rear-ended more than in the past. The Ann Arbor Transportation Authority is testing a collision warning system comprised of a four-foot-wide bar of eight LEDs. The pattern of lights moves out from the center, activated when radar detects something approaching the bus from the rear too fast. This "slower" illumination pattern was found to be easier for drivers to process and respond to. The test will measure if the buses with the LEDs experience fewer rear-end collisions. The complete document is available from Bobit Publishing Company (http://www.bobit.com/home.cfm)- Phone: 310-533-2400; FAX 310-533-2500.

On the Back of the Bus

University of California Transportation Research Center.
Access, Fall 2002: page 17.
http://www.uctc.net/access/access21.pdf.
This research focused on a device to reduce rear-end collisions. The subject of this report is a lightbar comprised of eight separate units, mounted on the rear of a bus at about eye-level to approaching drivers. It would be used in conjunction with a detection system on the rear of the bus that would cause the lights to fire when it sensed an impending collision. Replacing incandescent bulbs with LEDs significantly reduces the time needed for the bar to light. Tests indicated that igniting the eight units sequentially enabled observers to see them significantly sooner: enough to provide an extra 4.4 feet of stopping room on average for a car traveling at 30 mph.

Maintenance Vehicles

Washington State Department of Transportation

WSDOT is currently testing LED light utilization in certain vehicle applications. Curt Gegoux, NW Region Equipment Superintendent, said that WSDOT has tried LEDs in equipment hauling trailers and in mobile attenuator cushion trucks that are subjected to excessive vibration and excessive vehicle electrical load. "The jury is still out regarding their longevity and overall cost saving," Curt said. "However, it does look promising."
For more information, Curt may be contacted at- E-mail: gegouxc@wsdot.wa.gov; Phone: 206-768-5821.

Wisconsin: Marquette County

Contact: Lee Sauer, Shop Manager, Marquette County Highway Department.
E-mail: lsauer@co.marquette.wi.us; Phone: 608-297-9127.
On new patrol trucks on state sections, one of the three sets of red stop/tail/turn lights is now LED. The trucks are also equipped with amber LED rear alternating flashers, and an amber LED arrow stick mounted on the back of the rear snow foil. The arrow stick flashes multipatterns to direct and warn traffic. Non-interstate trucks are equipped with amber LEDs on the outside of mirror brackets, front-facing. Interstate dual-wing trucks are equipped with red LED stop/tail/turn lights on the tips of the wings, rear-facing.

"We use so many lights that we started using LEDs to reduce stress on charging systems," Lee said. "We started up on a limited basis with new vehicles and expanded to more vehicles in our fleet as their existing systems needed replacement. We are now seeing many additional benefits, including longevity.

"There were few startup issues," Lee said. "Compared to strobe systems, LED wiring is less complex and the startup cost is less. LEDs are slightly more expensive when compared to flashing standard incandescent systems. If replacement is needed, LEDs are somewhat more expensive than standard bulbs, but less frequent service is required. Colors are cost issues, but in time they have all seen reductions in cost, white currently being the highest cost for us. To some extent we wait until competition drives down the cost."

Lee said that, on the whole, he is pleased with the performance of LED lighting. "However, LED lights must be mounted flush or beyond when used in deep housings or behind grills etc. They do not project as well as maybe a strobe type would, making them less effective in those areas."

From: *Safer Winter Maintenance*

Better Roads, October 2003.
http://www.betterroads.com/articles/oct03c.htm.
LED lights are mounted on some states' snow plow vehicles:

- Idaho Transportation Department
  ITD is using LED taillights on all snow plow trucks.
  Contact- Dave Jones, State Maintenance Engineer;
  E-mail: djones@itd.state.id.us; Phone: 208-334-8400.
- Minnesota Department of Transportation
  Mn/DOT is trying a few LED lights.
  Contact- Office of Maintenance, Equipment Section;
  E-mail: equipment@dot.state.mn.us.
- Vermont Agency of Transportation
  VTRANS is experimenting with LEDs mounted on the discharge end of the wing plow.
  Contact- George Combes, Superintendent;
  VTRANS Maintenance Division- Central Garage;
  E-mail: george.combes@state.vt.us; Phone: 802-828-2564.
- Colorado Department of Transportation
  CDOT is placing an LED warning light on the end of the wing plow.
  Contact- Doug Boettcher, Equipment Manager;
  E-mail: Douglas.Boettcher@dot.co.state.us; Phone: 303-273-1852.

Enforcement Vehicles

University of Wisconsin-Madison Police Department

Contact: James Kaszubski, Security Supervisor;
E-mail: jpkaszub@wisc.edu; Phone: 608-262-4534.
"All of our fully-marked squads have all-LED lightbars," James said. "Over half of our non-striped cars have LED lights in them, and as our other lights need to be replaced they will be replaced by LED lights. Our lightbars have red and blue to the front and sides, with red, blue and amber to the rear. The amber color is used in the arrow stick mode to help direct traffic. All of our LEDs are used in a flashing mode as a warning to traffic.

"We are quite satisfied with the LED lighting," James said. "LED lights appear to be brighter and are visible during all weather conditions. With no moving parts there is less maintenance and there is no noise when they are being used. It takes approximately 70 percent less power to run LED lights, which in itself is a major consideration in view of all the electrical equipment being installed in squads now. Our lightbars are low profile, giving us better gas mileage and more of a stealth look when traveling on the road. In our squads without lightbars, the use of LED lighting has given us even more of a stealth appearance as LED lights do not have bulbs which are colored."

James said that the department decided to go to LED lighting in April 2002. Some of the reasons were the amount of power needed to run LED lights, projected maintenance cost over a 10-year period, stealth look of LED lights and cost projected over the expected life of the lightbars. "Our old lightbars were averaging 10 years of age and were no longer cost effective to run considering maintenance cost," he said.

James noted that startup costs can vary greatly depending on lightbar type and function. The department's lightbars cost $1,300-plus apiece, which included installation. However, the cost will vary, depending on the number of lightbars purchased at one time. "As with most products the more items purchased the lower the cost per item," James said. "The LEDs used in our unmarked squads are approximately $435 because they use fewer LEDs and do not have all of the functions of the full lightbars. The blue LED light is the most expensive, followed by red and amber. At this point our maintenance costs have been nil. As all of our LEDs are within five years of age they are all covered by warranty.

"Scheduling of the change over (to LEDs) is extremely important," James said, "because you do not want to take your entire fleet down at one time just to install new lighting. The main issue we had at startup was training in the use of the LED lights. The new lightbars had more functions than our old ones, and training was needed in how to get the lightbar to do what you want. This training was minimal, though, and was usually accomplished within 10 minutes."

James knew of law enforcement agencies in several Wisconsin municipalities that are using, or plan to use, LED lighting on vehicles. "Fall River and Bulter both have LED lights on their squad cars, Madison is doing testing with different style lightbars and Verona will be installing LED lighting in some of its squads shortly.

"Our agency is more than willing to show and explain our use of LED lighting to anyone who wants to stop by and see our setup."

Equipment

Curt Gegoux, NW Region Equipment Superintendent, Washington State DOT

E-mail: gegouxc@wsdot.wa.gov; Phone: 206-768-5821.

"There are four generations of LED lights. The use of generation 3 lights is recommended until the cost of generation 4 LEDs becomes less prohibitive. In my opinion, generations 1 and 2 should not be used because the effective angularity and intensity of emitted light is not safe enough for highway use."

American SuperLite

2002 product catalog: http://www.americansuperlite.com/catalog/2002.pdf.

American SuperLite specializes in vehicle safety lights for trucks, trailers and other vehicles. LED products include four-inch stop/turn/tail lights that use 15 LEDs in both red and amber versions, and are said to meet all DOT requirements. Unlike other LEDs that are fairly directional, these lights are said to have near-180 degree visibility by virtue of a unique lens design. Pricing information is available on request.

Truck-Lite

www.truck-lite.com;

Click on Catalog, Browse Catalog Online.

Items available under Catalog Search include LED lightbars, strobe lamps and cab markers. Truck-Lite claims that its stop/turn/tail lamp "paved the way for the usage of LED lighting in the industry," and that its LEDs have a life span approaching 100,000 hours. Pricing information is available on request.

SuperBrightleds

http://www.superbrightleds.com/truck_lights.htm.

LED truck lights for sale include 6.5 x 2.2-inch oval stop/tail/turn lights with 56 SuperBright red or amber LEDs. Pricing information is available at the site.

WANCO Inc.

http://www.wanco.com/AB%20Truck.htm.

The Vehicle Mounted Traffic Director.

This unit provides directional signaling from vehicles including snowplows, maintenance trucks and utility trucks. High output LEDs are available to lower battery power consumption. The device is available in sizes and configurations to meet most specifications and requirements. Pricing information is available on request.

Performance

What's new in: Lighting

Fleet Owner, Nov. 1, 2002.
http://fleetowner.com/ar/fleet_whats_new_lighting/.
Most fleets are aware of the advantages of LED lamps over incandescent lighting. The average life of an LED lamp -- which is not susceptible to shock and vibration since its electronics are completely sealed -- is 100,000 hours. (Incandescent bulbs are shown to last anywhere from 1,000 to 5,000 hours.) LEDs also consume less power. The total current draw of an average trailer equipped with LEDs, for example, is 85 percent less than one using conventional lighting.

An improvement in LED technology has enabled the output of individual diodes to be increased, so that even with fewer numbers of them they still meet all NHTSA and SAE requirements. The higher output LEDs have also made white LED technology possible, allowing LEDs to be used in more applications including backup lights and license lamps.

LED Lighting

Merls Bus Sales Inc.
http://www.merlsbussales.com/acc/led.htm.
LEDs light up about 200 milliseconds faster than incandescent lights. This is an important factor in braking applications, as it translates to one extra car length of reaction time at 65 mph. Also LEDs use about 10 percent of the amperage draw of conventional incandescent lighting, resulting in reduced wear and tear on a vehicle's electrical system.

American Trucking Associations (ATA) comments regarding LED lighting

http://www.truckline.com/safetynet/regulatory/103103_nhtsa.pdf.
This October 2003 communication from ATA responds to NHTSA Docket No. NHTSA 03-15651, which requested comment on a notice setting forth two draft interpretations concerning how the NHTSA standard on lamps, reflective devices and associated equipment applies to replacement equipment. (The docket may be viewed at http://a257.g.akamaitech.net/7/257/2422/14mar20010800/edocket.access.gpo.gov/2003/03-18110.htm.)
Excerpts:

- While not all commercial vehicles and trailers are equipped by the manufacturer with light emitting diode (LED) technology, the use of replacement LED lamps is a Recommended Practice (RP-143) of TMC, the industry group that recommends engineering and maintenance practices for commercial vehicle operations. These recommendations are reached through consensus by council members. Following recommended practice, LED use does not increase safety risks for vehicle operators or the public at-large.
- Because LED devices often contain many LEDs, they are more reliable in that should an individual LED in the assembly fail, the device is still operational and in compliance with FMCSA Part 393 Subpart B, Appendix G. With incandescent devices, if the bulb fails the entire component is no longer operational.
- Due to their superior performance, lower frequency of failure (e.g. longer service life), and redundancy (multiple LEDs per device), overall vehicle safety is enhanced.
- Under braking LED lamps have been found to come on nearly 2/10 of a second quicker than incandescent bulbs, which could alert following vehicles to a panic stop up to about 20 feet sooner.

Transportation Synthesis Report

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LED Warning Lights for DOT Vehicles
Supplementary Information – Vermont DOT

Prepared for
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WisDOT RD&T Program
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Request for Report

The following information serves as a supplement to Transportation Synthesis Report *LED Warning Lights for DOT Vehicles* (WisDOT RD&T Program, Dec. 10, 2003). In the course of preparing that report, several state DOTs were surveyed by email for information about their use of LED lights on maintenance and enforcement vehicles. The report was finalized prior to receipt of all of the responses. As responses are subsequently received, they will be published as supplements to the report.

Latest response received from:

VTRANS Maintenance Division- Central Garage;
George Combes, Superintendent;
E-mail: george.combes@state.vt.us; Phone: 802-828-2564.

Vermont made the LED body marker and ICC lights standard on plow trucks in 1996. The body stop/tail/directional was made standard equipment in 2000. LED strobe lights were made standard for the body rear corner posts in 2003. All the lights are interchangeable with the incandescent lights used prior to standardizing on the LEDs. The strobe lights do require a change in wiring. No retrofit program was set up to convert the older vehicles, however sometimes an LED is used to replace a failed incandescent light.

Where possible we are standardizing LED lights on all trucks that have a body installed by other than the chassis manufacturer. Colors would be amber or red and some are steady lights and others have flash modes. Additionally we are using some LED strobe lights on these trucks in place of the traditional strobe lights. These are flashing amber. On our enforcement vehicles we are using a mixture of strobe lights and LED strobes. These are blue, amber or white depending on the position they are used in.

Clearly we are satisfied with the LED lights and LED strobes or we wouldn't be expanding on their use. Lower amperage draw was the primary reason for trying the LED lights to replace the incandescent lights. We quickly recognized that our maintenance costs dropped and it wasn't because of the five-year warranty. The LEDs stand up much better than an incandescent. This is particularly true on applications were there is a lot of vibration. If a diode fails on a LED light you still have light as the other diodes are still functional. With incandescent lights if the bulb fails you have lost the light. In the case of LED strobe lights we have found that some have better penetration than a

regular strobe light. They are brighter from a distance and less as you close in reducing the "blinding" effect that motorists complain about.

As stated the initial decision was based on lower power requirements.

The start up cost for LED lights is the difference in the light cost. Everything else is the same. They are interchangeable. LED strobe lights require different wiring than regular strobe lights. The installation cost still basically boils down to the difference in the cost of the lights:

- round marker lights- $2+/- red and amber, round LED marker lights- $5.75+/- red and amber;
- stop/tail oval light- $4.75+/- red, stop/tail oval LED light- $25.00+/- red;
- corner post oval strobe light- $50+/- amber, corner post oval LED strobe- $77+/- amber.

There were not any start-up issues.

As stated our maintenance costs with LEDs is minimal. We have had very few lights fail.

We do use a mixture of regular strobes and LED strobes on our enforcement vehicles. Again power draw is an issue and the better light penetration helps from a safety aspect.

Generally we have found that in the directional applications the LED outperforms the standard strobe. Non-directional, the standard strobe is typically better. There are a lot of lights and lighting systems on the market. Try to get the vendor to provide lights for evaluation and try different setups and combinations before adopting one as a standard. Testing in actual field use is the only way to perform a lighting system evaluation. LEDs are rapidly being developed in different lighting shapes and styles. Keep in close touch with your vendor. Our primary vendor is Whelen Engineering. We have an excellent working relationship with them. They do allow us to field test new model lights that we feel we have a good application for.

Some of the municipalities in Vermont are using LEDs.